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ABSTRACT

The recent studies emphasize the importance of modern technologies and the reduction of gases emission while neglecting the significance of the optimum fuel. A comprehensive comparison for compressed natural gas, liquified natural gas, liquified petroleum gas, gasoline, electricity, diesel, and alternative fuels such as bioethanol and biodiesel as a transport fuel is carried out for Pakistan. The comparison is carried out by undertaking various factor that affects the fuel economy. Therefore, a comparison of fuel properties, production, consumption, emission of gases, engine performance and economy are carried to observe the optimum fuel for Pakistan. It concluded that compressed natural gas, electricity, and alternative fuels were found to be the optimum fuel for the environment and economy of Pakistan and having a high potential for its availability through different sources. Besides, strategy and future policies and directions are also discussed for the optimum fuel. Moreover, the future of vehicles is also discussed to analyze the transportation trend of the world. The present study will be very efficient for the optimum fuel consideration and growing future for developing countries. Therefore, Pakistan should pay attention to these fuels for their production, implementation, and electric vehicles for a sustainable future.

1. Introduction

In this era, imagining a life without fuel is impossible due to the wide spectrum of its applications. The energy sources majorly include renewable and non-renewable sources. Non-renewable energy sources, especially fossil fuels, are the most frequently used [1]. The fossil fuel, which consists of coal, oil, natural gas, and peat are used everywhere in the sector of households [2], industry [3], transportation [4], agriculture [3] and power generation [5]. The developing countries like India, Pakistan, Afghanistan, and Bangladesh are majorly lying on fossil fuels such as gasoline, diesel, CNG, LPG, and coal for the ongoing work in the industry, transportation, agriculture, and power generation. With the increasing demand for energy with the population, The world is gradually moving towards serious power crises due to the depletion of non-renewable sources worldwide [1].

Pakistan is an oil-importing country, to fulfill fuel requirement Pakistan spends a large amount of its budget on fuel importing. During July–March FY-2019, Pakistan imported 6.6 million tons of oil from the international market which worth a valuing of 3.4 billion USD [6]. The inflation rate is also a significant factor which affects the economics of fuels and ultimately all the sector. The hikes in fuel prices affect the automobile, power generation, and agriculture sectors. Due to hikes in fuel prices and depletion of fossil fuel reservoirs, the world's moving towards renewable sources like alternative fuels [7–9] for economically and environmentally stable fuel [10] along with utilization and optimization of waste energy for the pre-installed equipment [11,12] respectively to fulfill its requirement. Unfortunately, Pakistan is failed to implement advanced technology to utilize alternative fuels. However, in some areas of Pakistan, some renewable energy projects are installed such as solar [13], wind [14], and biomass [15]. The different energy

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sources are presented in Fig. 1 [16].

Besides all this, mobility is increasing exponentially due to population growth, which increased the fuel demand for transportation and increases gas emission [6]. Pakistan is the developing country where vehicle standards and labels are not properly defined and implemented. Due to this, the rate of gas emission is higher than the restricted limits given by the European Union (EU), which significantly affects the environment as well as human health [17].

A study on the recent literature shows that the world is moving toward alternative fuels and has a major concern on the gas emission rather than the economics of fuels. A review study conduct by Shahid and Jamal [3] reported that biodiesel is the most suitable alternatives fuel for short-term running engines with less brake power and gas emission and high fuel consumption compare to pure diesel. Likewise, Yeh [18] reported that developing countries like Pakistan and India have a high rate of natural gas adoption due to the energy crisis. Harijan et al. [19] suggested Pakistan should use ethanol blend in gasoline as an alternative fuel to reduce the 5-10% consumption of gasoline by the year 2030. Khan and Dessouky [15] showed the prospectus of biodiesel in Pakistan and compared it with gasoline, and suggest that biodiesel is cheap and environment safe over gasoline.

Yasar et al. [20] compared the compressed natural gas (CNG) with other fuels and suggested that natural gas is cheap and has low gas emission. Similarly, Hameed et al. [21] compared liquefied petroleum gas (LPG) with other fuels. They reported that LPG does not have low emission but economically good along with better mileage relative to other fuels. Liu et al. [10] reported that the use of hydrogen fuel cells for electric vehicles reduces the 15–45% emission of gases. Raza et al. [5] reported that the use of fuel cells in Pakistan would be sustainable development due to an abundance of renewable sources in Pakistan because of its geographic location. However, recent studies in Pakistan and worldwide are focused on alternatives fuels for environmental sustainability.

From the above literature review, the world is currently focusing on renewable energy sources, reduction of emission gases, utilization of alternatives fuels like biodiesel, bioethanol, and fuel cells and vehicles such as hybrid and electric vehicles (EVs). In contrast, the economic aspect of different fuels is not discussed. Due to the increasing inflation rate and energy crisis day by day, the economics of fuels have a great impact on the economics of the developing country. That is one of the major issues that have to address so that an economically and environmentally stable fuel is implemented for the development of the country. Therefore, with such an aim, an economic comparison is carried out for gasoline, diesel, CNG, LPG, and alternative fuels based on fuel properties, consumption, availability, performance, and gas emission.

2. Methodology

2.1. Description of the geographic location of Pakistan

The current economic comparison is carried for different fuels such as gasoline, diesel, LPG, LNG, and alternatives fuels for vehicles of

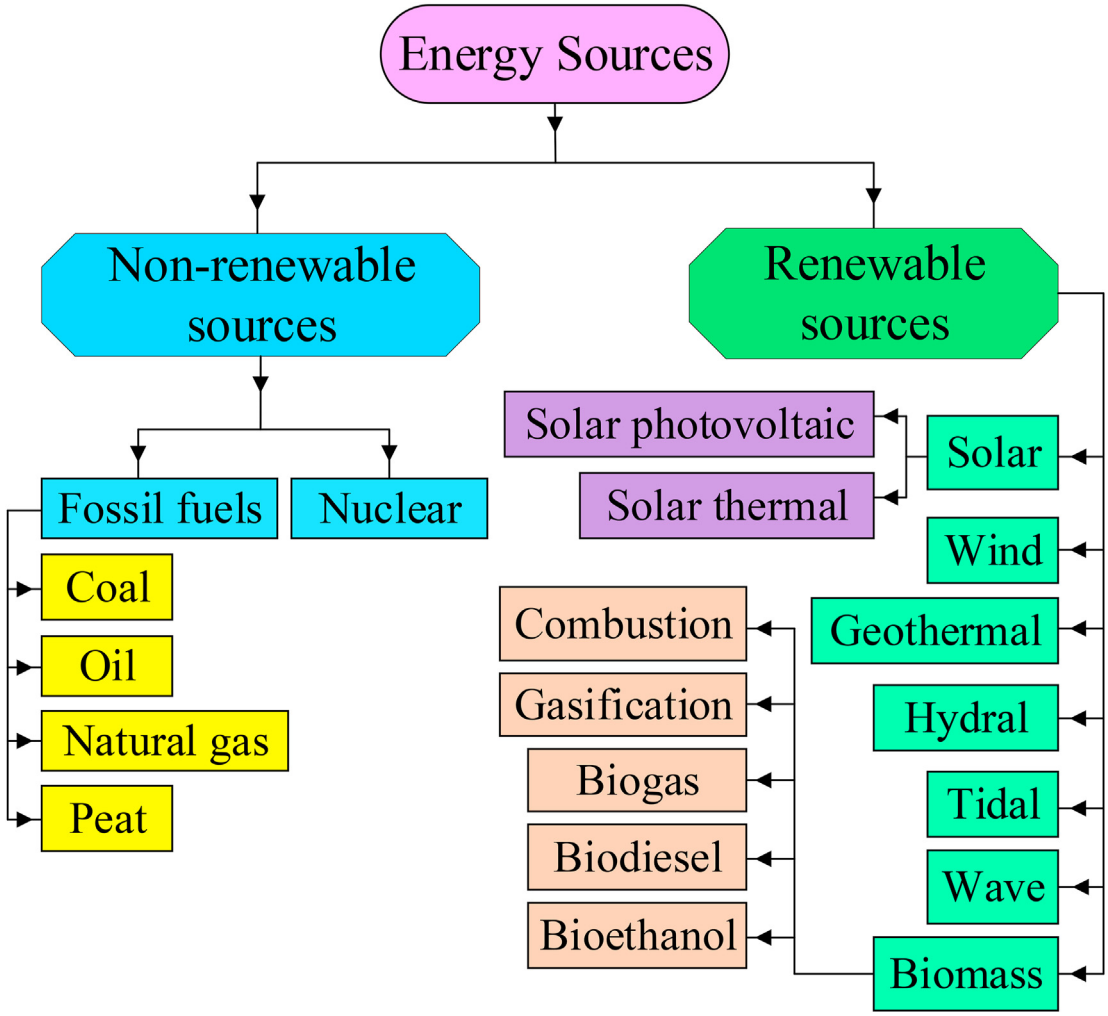

Fig. 1. Classification of energy resources via different routes [16].

geographic location Pakistan. Pakistan is a developing agricultural country with a total land area of approximately 796,096 Km^2 located in the region of South Asia. Moreover, the north, east, and west border of Pakistan is attached to Afghanistan, India, and Iran, while the Arabian Sea and china lie in the south and northeast. The people of Pakistan experience different weather and climate throughout the year like winter (November to March), summer (April to July), and the rainy season (July to September) [22].

3. Energy fuels potential and transportation in Pakistan

3.1. Energy overview

Pakistan is an energy deficient country and having limited resources of oil and gas reserves and depends upon the importing of oil and other resources so that it can utilize in different sectors such as household, transportation, agriculture, industry, and power generation. However, Pakistan fulfills some of the energy requirements through renewable energy sources that most common in Pakistan are hydro and solar. The total electricity generation in Pakistan reached 34.2 GW for FY-2019, which was at 34.4 GW for FY-2018 with 2.5% growth in electricity generation. The generation through all the non-renewable and renewable sources has increased from 82,011 GWh to 84,680 GWh with 2.1% growth [6]. The generation of electricity that comes from different sources is illustrated in Fig. 2 [6].

The highest contributors are hydroelectric with 25.8% and thermal power plants with 63%. In thermal power, furnaces, boiler, gas turbine, engines are running on oil, gas, petroleum products, and coal. To fulfill the non-interrupted requirements of the thermal sector, oil, gas, petroleum products, and coal are provided by extraction and importing. The list of extraction and imports is given in Table 1 [6]. The imports (refer to Table 1) are increased with the energy crisis. Thus, the prices of imports affect significantly.

3.2. Energy fuels potential

The quantity of fuels is reducing with the increasing population; therefore, it is compulsory to find an alternative to fulfill our energy requirements. The major consumption of fuels in Pakistan is due to transportation, industry, and the power generation sector. In Pakistan, the consumption of petroleum products amounts to 19.68 million tons per year, compared with the supply of 11.59 million tons per year from local refineries, while the remaining 8.09 million tons are imported [6].

The consumption of oil and petroleum products is presented in Table 2 [6]. The consumption of oil and petroleum products are followed as transport > power generation > industry > other projects of government > household > agriculture. Simultaneously, the potential for oil and petroleum products is reducing due to the depletion of fossil fuels with a specific period. Therefore, it is concluded that in the upcoming years, the prices of oil and petroleum reaches a peak due to high demand and low supply.

Likewise, Pakistan produces about 4 billion cubic feet/day (Bcfd) of indigenous natural gas against an unconstrained demand of over 6 Bcfd. The government of Pakistan has initiated the importation of LNG to meet the shortfall [6]. The consumption of gas is represented in Table 2. The consumption of gas as follow, are power generation > household > industry > fertilizer > transport > and commercial sector. However, the potential of natural gas in Pakistan is high and has a low cost. Due to this reason, natural gas adoption is rapidly increasing in Pakistan. However, eventually, natural gas reservoirs will also deplete, and a severe energy crisis would happen. Therefore, alternative fuels are compulsory due to the requirements. Alternative fuels like biodiesel and bioethanol having high potential due to the excess amount of ethanol and methanol.

Methanol is preferred over ethanol due to its cheap rates. The methanol is produced from coal, and Pakistan is rich in coal, having more than 185 billion tons of coal reserves, which are the world's 5th largest [23]. Likewise, ethanol potential is also very high due to 76 sugar mills having a sugarcane crushing capacity of 7500 million tons per day [24]. Currently, there is 21 distillery unit which can produce 400,000 tons of ethanol which can use as blends with gasoline and reduce the consumption of gasoline up to 5-10% [19]. Pakistan is also known as an agricultural country with 70% of its population working in the fields. The unused land reported to 28 million hectares which can be used to produce biodiesel from Jatropha plant seeds that required low water that can produce 56 million tons of biodiesel per annum while the requirement of diesel is 8.7 million tons [6,25] that can be available for the transport and

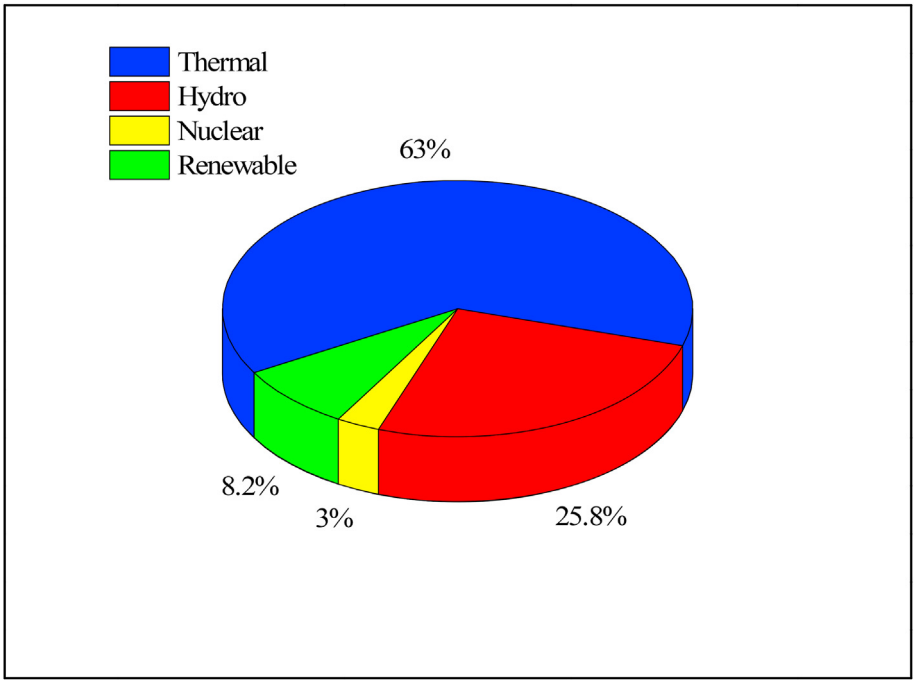

Fig. 2. Electricity generation from different sources in Pakistan from 2018 to 2019 [6].

Table 1
Imports and extraction of different fuel products in Pakistan [6].

Fiscal Year	Oil (Thousand barrels)		Gases (million cubic feet)		Petroleum products (Thousand Tons)		Coal (Thousand Tons)	
	Import	Extraction	Import	Production	Imports	Production	Import	Production
2017–18	60,334	21,754	192,226	978,246	7749	7937	8197	3386
2018–19	51,470	24,657	269,246	1,080,721	6492	8096	11,000	1512

Table 2
Gas and Oil/Petroleum consumption by different sectors in Pakistan from 2018 to 19 [6].

Sectors	Gas (mm cft)	Oil/Petroleum (tons)
Household	311,887	60,557
Power generation	511,140	2,759,465
Industry	246,706	299,437
Transport	65,099[a]	14,673,564
Agriculture	–	15,021
Other Govt.	–	409,132
Commercial	31,205	–
Fertilizer	233,834	–
Cement	387	–
RLNG	53,261	–
Total	**1,453,519**	**19,217,176**

—: Not available.
[a] Transport: CNG.

power generation sector.

3.3. Transportation

The growth of vehicles is increasing exponentially due to the high rate of the population. Hence, the fuel consumption is also increasing rapidly by the transport sector. Therefore, the prices of fuels affect the economics of mobility holder dominantly. The production of vehicles for 2018-19 is presented in Table 3. The highest productions are as follow, motorcycle/rickshaw > cars/jeeps > tractors > light commercial vehicles > trucks > buses.

4. Evaluation of various fuels in Pakistan

4.1. Fuel properties

Every fuel keeps a unique property that is either superior or inferior according to the utilization and environmental conditions of the fuel, such as gasoline has a lower flash point but higher ignition temperature. That is why a spark plug is needed to ignite the gasoline, but diesel is easily ignited through compression. Likewise, CNG and LNG have similar flashpoints and ignition temperature but a huge difference in the viscosities and densities. Which means they cannot be used in the same type of engine. Similarly, ethanol has a very low flash point but greater than gasoline but a significantly small range of heating value. This moderate behaviour in properties makes ethanol comparable with other mentioned fuels. It emphasizes the increment of its utilization. Consumers are supposed to pay attention to the utilization of ethanol. Although biodiesel also has fair chemical and physical properties, its production still needs the government's attention and competent authority that deals with such matters. The properties of different fuels are illustrated in Table 4 [26, 27].

Table 3
Production of different Motor Vehicles in Pakistan from 2018 to 2019 [6].

Motor Vehicles	Production (In Nos.)
Motorcycles/Rickshaws	2,459,849
Buses	913
Cars/Jeeps	216,780
Trucks	6,035
Tractors	49,902
Light Commercial Vehicles	24,453
Trucks	53,261

4.2. Consumption and production of fuels

Pakistan is rich in natural resources but unfortunately poor in technology, mechanical resources and having huge debt by the international market, Pakistan is unable to extrude oil and other resources up to its requirements. Liquified petroleum gas (LPG) is seeking attention with its 11.3% growth in consumption. In comparison, the production of LPG is 59.11%, and the remaining LPG is importing with a share of 40.88% annually for FY-2019 [28], which economically affects the LPG. On the other hand, the consumption of diesel (HSD) and petrol (MS + HOBC) is almost the same for vehicles in Pakistan, but production by refineries is very low. The production by refineries and consumption by the transport sector is represented in Fig. 3 [29–31]. Therefore, importing oil is necessary to fulfill energy losses that increase the prices of the fuels. The demand-supply gap in oil products increases day by day with the depletion of fossil fuel reserves in Pakistan.

If Pakistan could utilize its natural resources and extract own oil, then it might be beneficial. However, in the current circumstances, it is not economical for the customers. The contribution of natural gas to the energy supply is higher than oil due to surplus reserves in Pakistan, and it is also economically and the environment safe. However, unfortunately, due to the high rate of gas consumption, Pakistan had started importing gas since 2015, which affects the prices of gases and byproducts of gases. The gas production for FY-2018 is 4357 million cubic feet per day (MMCFD) while the demand-supply gap is 1447 MMCFD which tends to increase 3613 MMCFD for FY-2020 [30]. Thus, it concluded that gas prices would also be increased in the future. Fortunately, Pakistan is an agricultural country having a great potential for ethanol and biodiesel which is reported as 0.42 million tons per annum [19] and 56 million tons [15] respectively.

In recent age, the consumption of ethanol and methanol is not reported but these alternative fuels are economically and environmentally beneficial due to high potential and low emission of these fuels, respectively. Therefore, the government of Pakistan should provide attention to these alternative fuels as the world is also moving toward alternative fuels. Based on the current scenario, it is concluded that CNG is the best economical solution for vehicles. Although there are some drawbacks and hazards in the use of CNG, it can hold the economy for a couple of years until turn the way of technology towards electric, hybrid vehicles and alternatives fuels, which are considered as the most economical and efficient fuel solution globally.

Table 4
Evaluation of fuels based on different properties [26,27].

Fuel	Flash Point (°C)	Density (kg/m^3)	Kinematic Viscosity (m^2/s)	Heating Value (MJ/kg)		Ignition Temperature (°C)
				HHV	LHV	
Gasoline	−42	750	0.5×10^{-6}	45.7	42.9	246–280
Diesel	50	830	3.0×10^{-6}	47	43	210
CNG	−187	0.72	7.8×10^{-6}	55	50	537
LNG	−188	430	1.6×10^{-6}	50	45	537
Ethanol	12	785.5	7.0×10^{-6}	27.4	21.2	423
Biodiesel	129	916	5.8×10^{-6}	40	–	149

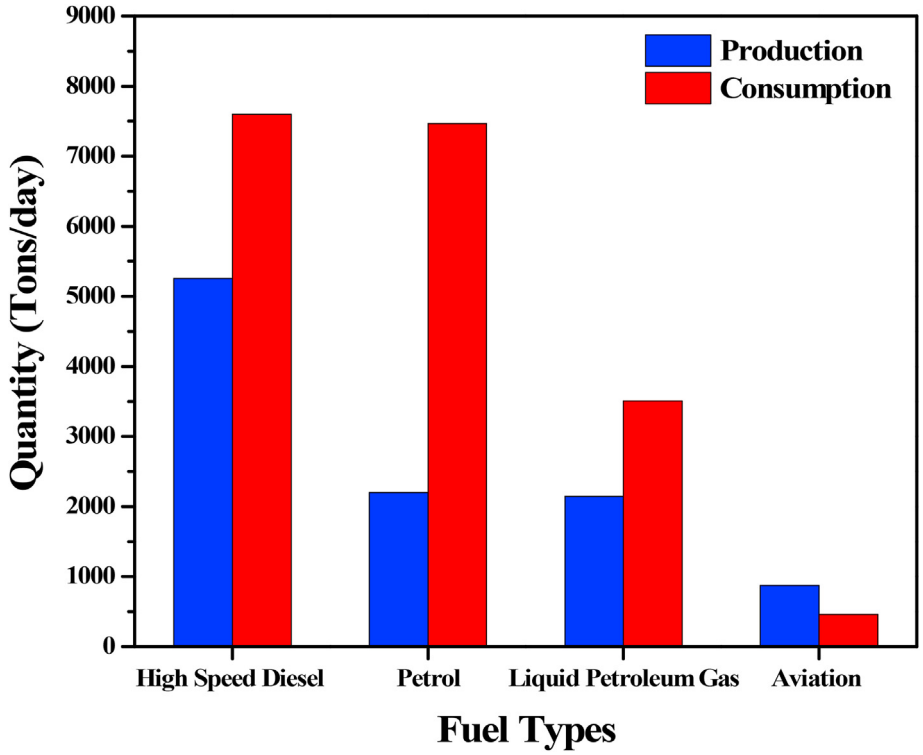

Fig. 3. Consumption and production of oil/petroleum products in Pakistan for the year 2018 [29–31].

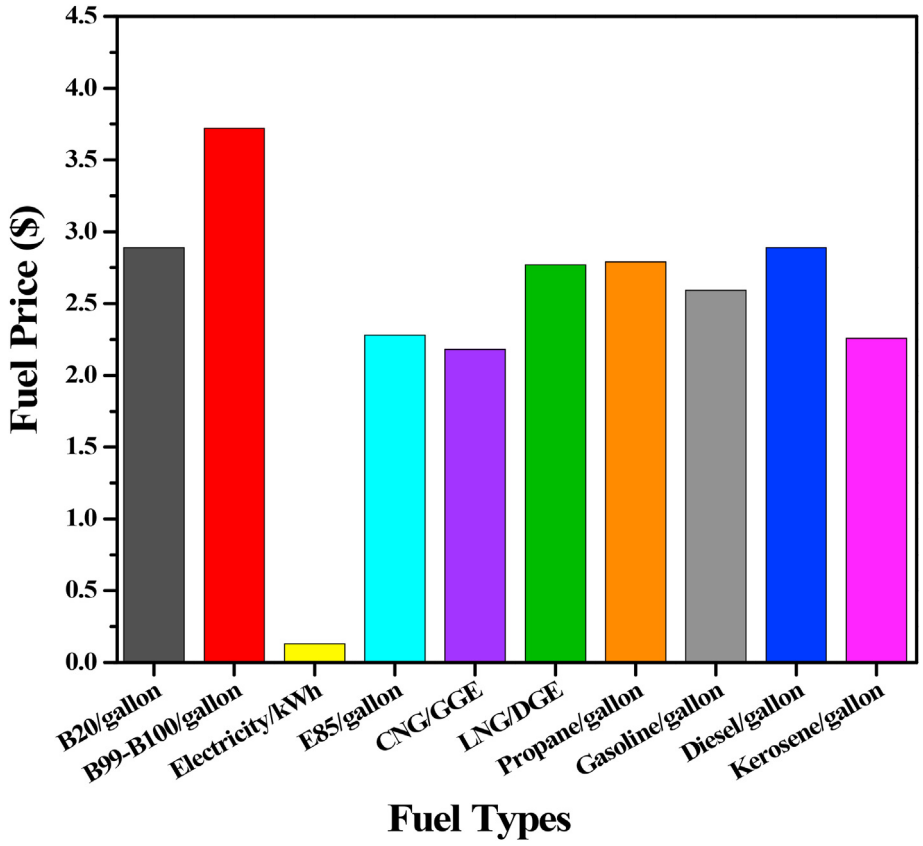

Fig. 4. Comparison of different fuel prices in Pakistan [6,32,33].

4.3. Economics of fuels

Economics plays a vital role in the development of a firm or country. The world is going towards the most economical but efficient solutions. It's apparent in the graph that electricity is the most economical fuel in the current conditions, as illustrated in Fig. 4 [6,32,33]. As described earlier that all the so-called vehicle production industries have set a deadline to obsolete the production of gasoline and diesel vehicles, and they will update their plants for the production of hybrid and electric vehicles (EVs) until that time. However, it is a red signal for Pakistan's

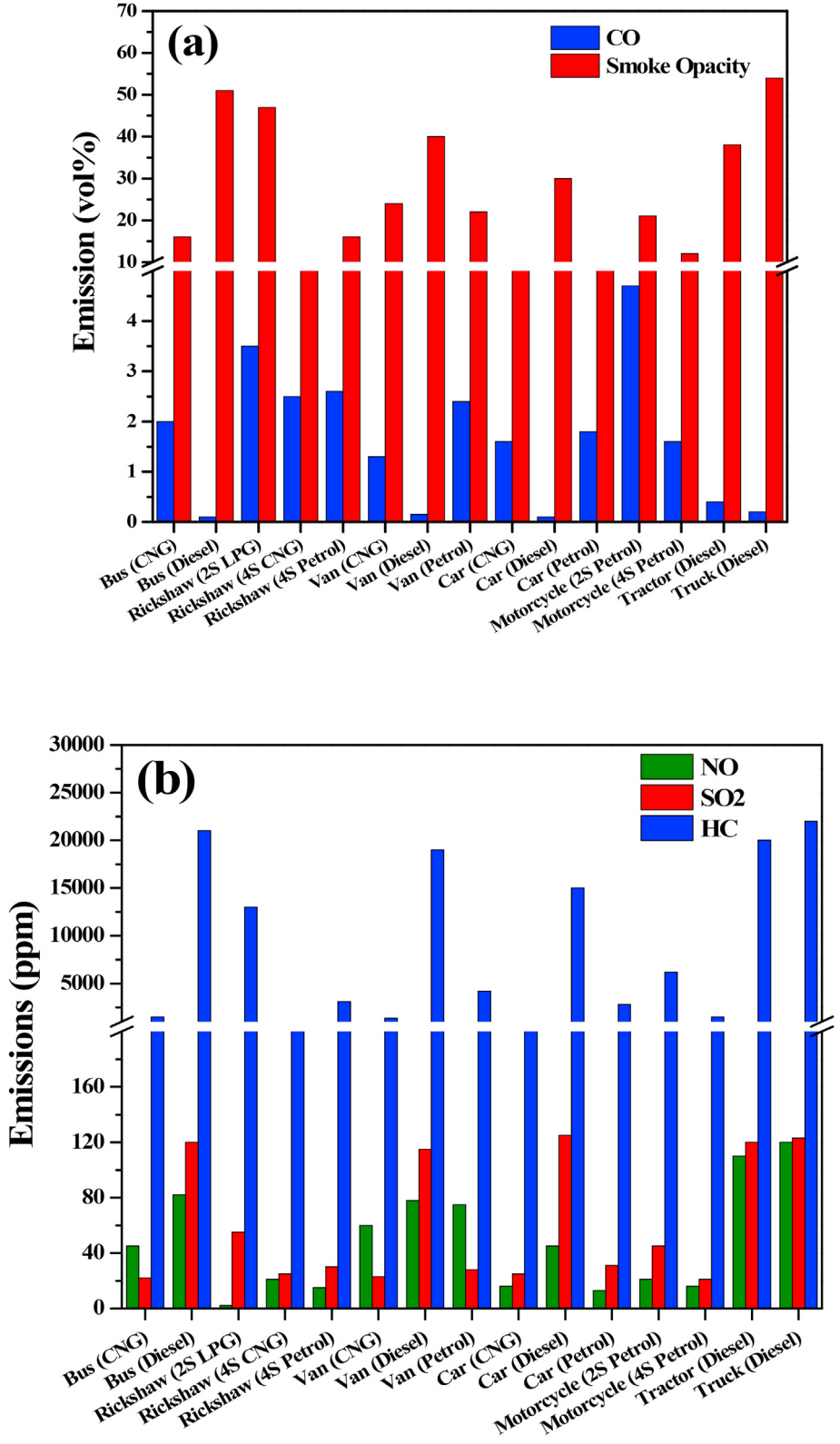

Fig. 5. Pollutant emissions from different vehicles; (a) Carbon monoxide (CO) and smoke opacity; (b) Nitric oxide (NO), Sulphur dioxide (SO_2), and Hydrocarbon (HC) [20].

future vehicle. Although gasoline and diesel are widely used and it is not economically feasible, Pakistan has to import a huge amount of crude oil to fulfill the demand-supply gap each year. However, an effective way to spend that amount in producing electricity and follow the world trends of vehicles is obvious it can save a considerable amount of money that used to import oil every year and can use that in the development of the country. Fossil fuels are going down day by day and their prices are getting higher with each passing day; that is an alarming situation.

It is important to mention that for the generation of power (electricity), the thermal power stations consume 14.3% oil/petroleum products and 36.5% gases annually. Still, majorly the reserves are utilizing in the transport sector. Meanwhile, the power need fulfilled by renewable sources is only 3.89%, which has to be increased. Therefore, customers get cheap electricity as compared to thermal power stations. By implementing the latest technology, the electricity generated by renewable sources such as solar, wind, biomass, and tidal will be more than enough for electric vehicles. It ultimately reduced the dependency on the traditional vehicles with SI engines that consider being less efficient has high emission of gases. Meanwhile, focusing on traditional fuels [6,33] and alternative fuels [32], the prices of biodiesel (E20/gallon) and liquified natural gas (LNG/DGE) is low as compared to pure diesel. Likewise, ethanol (E85) and natural gas (CNG/GGE) have fewer gasoline prices. It shows that alternative fuels and CNG are the most economical fuels after electricity.

4.4. Emission of fuels

The emission of gases also has a significant impact on prices because the emission reduction technologies are ignored, the investment in the reduction of emission gases is reduced and ultimately, the product cost of fuels is reduced, but it is not favourable for the environment. If a certain fuel has low emission, then there is no need for any emission reduction technology that results in benefit on the economy of fuel along with the vehicles. The emission of different fuels is represented in Fig. 5 [20]. For instance, in rickshaw and motorcycle, which has a very high production rate of 88.6% in the transport sector. The smoke opacity of LPG is very high for rickshaws compared to the motorcycle while carbon monoxide emission is high in a 2-stroke petrol motorcycle as compare to the rickshaw. Likewise, hydrocarbon has high emissions as compared to NOx and SO_2. The emission of hydrocarbons of LPG is very high for rickshaws as compared to motorcycles. Therefore, gasoline and CNG are more favourable due to low emissions. Besides, the emission of alternative fuels like fuel cell [5], bioethanol [19], and biodiesel [15] have low emission comparatively to gasoline and diesel. Therefore, it concluded that CNG and alternative fuel are safer for human health and the environment.

4.5. Effect of fuels on engine performance

In the spark-ignition engines, the ethanol impact has been observed over the years when it is used as an additive in the fuels. Experiments revealed that the 10% addition of ethanol could boost 5% of the engine power. This ethanol addition in the gasoline causes the increment in the fuel Octane number by five units as the result of a 10% addition of ethanol. Moreover, an extensive reduction of carbon monoxide of 30% has also been noticed in the emission through the exhaust [34]. Another study was conducted by Ewan et al. [35]. They compared the engine performance and exhaust emission on a spark-ignition engine by fueling natural gas and gasoline separately. They experimented with it over a broad range of air to fuel ratios on the different operation conditions. A reduction of 12% in the engine output power was observed when the natural gas-fueled it at the same throttle position. It happened because of the air displacement by the gas. Furthermore, a 5–50% reduction was observed in the natural gas emission level in terms of pollution.

Besides, the thermal efficiency was almost equal for both of the fuels. Besides that, because of the delay in the lean limit of burning, natural gas revealed an increment inefficiency. Likewise, Khan and Dessouky [15] reported that biodiesel provides a 10–15 point higher cetane number, which improves combustion while 10% less energy density. Biodiesel also increased the engine life due to better lubrication as compared to diesel. Similarly, Jahirul et al. [36] investigated the gasoline and CNG and reported that CNG produces low brake power than gasoline and brake specific fuel consumption (BSFC) while having better thermal efficiency. Moreover, CNG produces low emissions as compared to gasoline. Besides, Therefore, based on recent studies, petrol and diesel have high power relative to natural gas and alternative fuels, but biodiesel and ethanol also have a beneficial effect such as low emission, better lubrication, long engine life, and better combustion but have disadvantages like high fuel combustion and low power.

5. Emission and environmental impact

The gas emission exits when the fuel ignites. The rate of gas emission is different for different blends of fuels. The main contributor to air pollution is vehicles. Some standards of gas emission can be found in every country to control air pollution, such as the most common are Euro Standards which is given by the European Union (EU) [17]. European Union set the limits of gas emission based on the transport medium. Unfortunately, Pakistan is one of the developing countries where transports manufacturers do not implement the latest technology and EU emission standard to control air pollution.

Due to this reason, the air pollution rate was increasing very rapidly in Pakistan and reported that the emission of carbon dioxide (CO_2) is 195.71 million tons annually in Pakistan while the total globally emission is 33.3 gigatons in 2018, which affect human health as well as the environment [37]. Therefore, the country needs economically favourable, along with environmentally friendly fuels. Therefore, some researcher is working on the utilization of CO_2 emission into alternative fuels [7]. The recent studies show that alternative fuels like fuels cell [5], biomass [38], bioethanol [19], biodiesel [15] and the latest technology such as electric, hybrid vehicle [39], multi-component fluidized bed [40] and emission catalyst (EC) [41] can reduce the emission of gases. Thus, we should implement these latest technologies and the most favourable fuel from an economic and environmental perspective.

6. Future trend of vehicles and fuels

6.1. Drawbacks and workspace

The classic traditional engines and technologies have many energy losses that significantly increase fuel consumption and reduces the efficiency of vehicles. The reduction of energy losses is very important in vehicles for efficient vehicles, but classic engines and retarded technologies have major losses. Therefore, the world is currently working on reducing energy losses that increase the efficiency and the fuel economy but tend to increase capital investment by introducing emerging technology. The emerging technology is a workspace where the world can work and make vehicles more efficient like japan, china, and the USA are currently working in that area for cost-effective and efficient vehicles.

6.2. Development in the transportation sector

In the future, the world automotive industry is becoming advance by collaboration with technology companies for the safest, efficient fuel economy and environmentally-friendly vehicles. The recent conduct studies show that the world move towards cost-effective fuel and efficient vehicles like Lemazurier et al. [42] tested the different engine and transmission technologies. They reported that fuel economy significantly improved for technologies such as friction reduction, cylinder deactivation, downsizing, turbocharging, 8-speed dual-clutch transmissions (DCTs) over Environment Protective Agency (EPA), standard combine cycle, 6-speed transmission, naturally aspirated (NA) engines through

variable valve lift (VVL) and gasoline direct injection (GDI). It is worth mentioning that a belt-integrated starter-alternator (BISG) offers a significant improvement in fuel consumption overall engine and transmission technology due to the reduction of losses in the idle run of vehicles.

Worldwide stats proved oil, gas, and coal reserves are 1688 billion barrels (Bbs), 6558 trillion cubic feet (TCF), and 891 billion tons (Bts), which are currently consumed worldwide widely at a rate of 0.09 Bbs, 0.33 TCF, and 7.89 Bts per day respectively. Due to the high rate of consumption of fossil fuel, it is predicted that oil, gas, and coal will end in the year 2066, 2068, and 2126 respectively [43]. Thus, the world move towards renewable sources and technologies likes hybrid and electric vehicles (EVs) and their efficient uses as Jaguemont et al. [44] suggested the solution cold temperature issues of lithium-ion battery for better efficient electrical vehicles (EVs) with ideal thermal management. Similarly, Wang et al. [45] showed the importance of an integrated thermal management system for optimal performance and lightweight of classic, hybrid and electric vehicles which improved the fuel economy, engine operation and reduce energy losses. Therefore, Tesla is an emerging company for electric and hybrid vehicles that efficiently covered hundreds of miles with a single charge. The consumer of electric vehicles is increasing as more than 2 million electric vehicles were sold worldwide in 2016.

Meanwhile, Volkswagen and general motor claim that they equipped all their engines with electric motor by 2019. Electric and hybrid vehicles are becoming more affordable and fuel-efficient as Hyundai, Kia, and Toyota companies revealed that hybrid vehicles are up to the $30,000 mark, suggesting that the world may soon be adopted fuel-efficient vehicles. However, based on current scenarios worldwide, the sales of electric and hybrid vehicles are expected to rise by 25% and 35% for the United States and China in 2030, respectively. On the other hand, modern vehicles are equipped with artificial intelligence (AI), machine learning (ML), catalytic converter, and advanced motor control system used for different purposes, which reduces fuel, gas emission, and electricity consumption while in the idle situation [46].

7. SWOT analysis

The Strength, weakness, opportunity, and threats (SWOT) analysis is carried out in Table 5 for the optimum fuels. In current scenarios, electricity, CNG, and alternative fuels such as biodiesel and ethanol are considered the optimum fuels.

8. Proposed plan

The above discussion reveals that Electricity and alternative fuel are the most suitable options for an energy deficient country having limited resources and reservations as well as facing fierce economic and environmental conditions. As obvious from the previous studies related to efficient fuel that electricity and alternative fuel could not reach to the utilization of mineral oils (Gasoline, Diesel). However, some serious steps towards their production and utilization strategies can make them stand beside these traditional fuels. It will not only benefit economically but environmentally because the emission of toxic substances is very low in these fuels. It should be added here, and no complete and comprehensive study was done for the production and consumption of vehicular fuels and their economic significance, which could provide a guideline for the selection of the most efficient and ecofriendly fuel. To revive these previous knockdowns studies, an apparent and economically feasible fuel significance is proposed to define future strategies and an economical fuel selection.

Although, in Pakistan, alternative fuel production like ethanol is so limited and it is not produced over the year. Sugarcane and corn are the widely used ingredients of ethanol. Last year (2019), Pakistan exported 342.82 million USD in sugar and sugar confectionery [47] and 6.8 million USD in corn [48]. On the other hand, Pakistan imported oil of 3.4 billion USD March–July FY-2019 [6]. If Pakistan stops the export of the described crops and utilizes them in producing ethanol, then that massive amount of oil import can be reduced to its lowest level. It will not only provide a huge contribution to the economy but will play a vital role in reducing the burden of fuel import. However, for that achievement, an integrated ethanol production approach is necessary. Hence, sugar mills owners get a considerable amount from that export. Therefore, they would barely accept the utilization of sugarcane in the production of Ethanol. In this scenario, there should be an agreement between the owners and government that nevertheless goes in their favour of them.

It would be only possible if facilitate and encouraging them to establish ethanol production plants.

The described strategy advocates that the ideal location for ethanol production plant should be beside sugar mills. So that they could easily produce sugar as well as ethanol and could maintain their profits in a way that is not only beneficial for them but the whole of Pakistan. Moreover, the byproducts of sugar cane and corn like bagasse, corncob, etc., can be used to produce electricity to run these co-generating plants. However, electricity is the best option as it is the most efficient and ecofriendly fuel but due to the unavailability of electric vehicles and lack of technical research and resources. Currently, it neither can be applicable nor can be advantageous, but for the economy but the future, it would be the economic and best alternative fuel. The government should follow the world trend and turn the face of our vehicular technology towards hybrid and electric vehicles. Also, focus on the production of renewable energy that can make it more economical.

Table 5
SWOT analysis for optimum fuels in Pakistan.

Strength	Reference	Weakness	Reference
• The prices of electricity, CNG, and alternatives fuels are low. • The availability of gas is 80% while the importing is just 20%. • The potential of alternative fuel is high as ethanol and methanol can produce up to 0.42 million tons and 56 million, respectively. • Emission is low for CNG, electric vehicles, and alternative fuels.	[6,15,19, 32,36,39]	• Transesterification of biodiesel is difficult • Capital investment for emerging technology • Higher fuel consumption of CNG and alternative fuels • The higher consumption rate of CNG • Emission of NOx is high for CNG	[1,3,36]
Opportunity	**Reference**	**Threats**	**Reference**
• Uncultivated land of 28 million hectares for the solar and alternative fuel crops • Surplus raw material (molasses) for the ethanol production of 0.42 Mts per annum • Coal reserves for production of methanol	[6,19,23]	• The engine wears due to alternative fuel usage • Cold weather affects the battery of the electric vehicle • Higher Emission of NOx affects the human health	[3,44]

9. Policy suggestions and future directions

The proposed study distinguishes the significance of ethanol and electricity as alternative fuels for eliminating the impacts of expensive mineral oils (Gasoline and Diesel etc.) over the economy and ecosystem. To make it all possible, such eccentric advancement is supposed to be controlled, maintained by government strategies and funding. A recent report published by NEPRA has sketched a scheme of generating electricity from various projects majorly including renewable, hydro, nuclear, and local coal to fulfill Pakistan's energy requirement. The hydro

and renewable energy project would supply 56% of electricity until 2040 [49]. It reveals that the government is constantly transforming the power generation into renewable resources by adding new solar and wind power plants, which is the demand of fuel evolution.

According to the MoST report in November, National Electrical Vehicle Policy (NEVP) has been approved by Pakistan with the 30% sales target of all passenger vehicles and heavy-duty trucks by 2030, which will be turned into 90% after a decade [50]. The implementation of EVs is beneficial as they are energy efficient and zero-emission vehicles. Besides, these policies can eliminate the dependency on oil-importing (worth 13 billion USD annually). The economic coordination committee (ECC) has constructed some policies on mineral oils and renewable power generation, but their implementation is indolent. Moreover, there are 76 sugar mills in Pakistan, producing ethanol from molasses of 2.5 million metric tons (MMT) [24]. However, it is seasonal production but still an appreciable contribution. If a corn-based ethanol production plant is also added, then the production can continue throughout the year. Some important steps that the government of Pakistan should adopt;

1) The government should design some term-based policies with a consecutive check and balance to manage all upcoming energy generation projects within a specified period.
2) A threshold should be set to produce sugar and sugar confectionery according to the annual demand of the country, the rest of the sugar cane and corn should be used for the production of ethanol.
3) Speed up the construction of renewable power plants, especially solar and wind to reduce the generation cost and manage the cost tariff deficits, and make their accomplishment certain until the electrical vehicles (EVs) are being launched in the market.
4) To use ethanol as the replacement of mineral oils, more efficient, interchangeable, and combined engines should be developed to reduce the dependency of conventional importing oil.
5) Experimental based research should be conducted in the educational institutions to develop more efficient electric and hybrid vehicles by collaborating with different automotive industries.

10. Conclusions

The comparison for CNG, LNG, LPG, gasoline, electricity, diesel, and alternative fuels are carried out for Pakistan. The study is conduct based on the following factors that affect the economics of fuels are fuel properties, emission of fuels, demand-supply, economic, and engine performance. Therefore, an evaluation of different fuels is conducted by considering the influencing factors to identify the optimum fuel for Pakistan from major aspects. The SWOT analysis is performed to identify the strength, weakness, opportunity, and thread for the optimum fuel in Pakistan. Besides, the future of vehicles and fuel is highlighted. Meanwhile, strategy, future policies, and directions are explained for optimum fuels. The findings of the current study are as follow:

- Every year Pakistan imports Oil/petroleum products, which affect the fuel prices, especially for MS, HOBC, and HSD. Besides, the CNG has high reserves which reduced its import (<20%) and make it an economically beneficial fuel.
- Electricity has the lowest prices as compared to gasoline and diesel. Meanwhile, the prices of E20, LNG, E85, and CNG are lower as compare to pure diesel and gasoline, respectively. It shows that from the monetary point, alternative fuels and CNG are the most economical fuels after electricity.
- Emission of gases is low for electric fuel, CNG, and alternatives fuels as compared to gasoline and diesel.
- Gasoline and diesel provide better engine performance in terms of brake power and fuel consumption as compare to natural gas and alternative fuels. Still, CNG and alternatives fuels have better thermal efficiency, lubrication, combustion, and engine life. However, in some cases, the engine is worn out due to biodiesel utilization in the long run.

Pakistan should move towards electric vehicles, as the world trend is inclined over efficient vehicles. The electricity in Pakistan is also very cheap as compared to conventional fuels. Thus, electric vehicles (EVs) will be a good initiative and the best solution for the economy and wholesome environment of the country. The findings of the current study contribute efficiently to predict the most favourable and optimum fuels for under developing countries. However, future work is needed to implement and production of optimum fuels for a sustainable and growing future.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Nomenclature

Abbreviations

AI	artificial intelligence
Bbs	billion barrels
Bcfd	billion cubic feet per day
BISG	belt integrated starter-alternator
BSFC	brake specific fuel consumption
Bts	billion tons
CNG	compress natural gas
CO	carbon monoxide
CO_2	carbon dioxide
DCTs	dual-clutch transmissions
DGE	diesel gallon equivalent
EC	emission catalyst
EPA	environment protective agency
EU	European union
EVs	electric vehicles
B20	diesel with 20% blends
E85	ethanol with 85% blends
FY	fiscal year
GDI	gasoline direct injection
GGE	gasoline gallon equivalent
GW	gigawatts
GWh	gigawatts hour
HC	hydrocarbons
HHV	high heating value
HOBC	high octane blending component
HSD	high-speed diesel
LNG	liquified natural gas
LLV	low heating low
LPG	liquified petroleum gas
ML	machine learning
MMCFD	million cubic feet per day
MMT	million metric tons
MoST	Ministry of Science and Technology
MS	motor spirit
NA	naturally-aspirated
NEVP	National Electrical Vehicle Policy

NEPRA	National Electric Power Regulatory Authority
NOx	nitric oxide
SO_2	Sulphur dioxide
SI	spark ignition
SWOT	Strength, weakness, opportunity, and threats
TCF	trillion cubic feet
USD	united states dollar
VVL	variable valve lift
WHO	world health organization

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